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RETURNS TO THE FISHERY AND ESCAPEMENT OF ADULT COHO SALMON FROM ACCELERATED AND NORMALLY REARED JUVENILES

by

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ABSTRACT

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Under normal hatchery operations, juvenile coho salmon (Oncorhynchus kisutch) are reared for at least 14 months before release to the sea as smolts. Reduction of the rearing period would reduce costs substantially. One means of reducing the rearing period would be to accelerate growth of the fish, resulting in the production of smolt-sized juveniles in a shorter period of time, at an earlier age. Such a technique also could have the advantage of increased generation time, whereby adults would mature in their 2nd rather than in their 3rd year of life.

In the fall of 1973, an experiment to accelerate growth of coho was initiated at Rosewall Creek on Vancouver Island. During the winter of 1973-74, approximately 10,000 coho were accelerated to the smolt stage in 6 mo through control of temperature, photoperiod and feeding rate. These were marked, nose-tagged and released on June 10, 1974, along with approximately 12,000 normally reared (14 mo), nose-tagged coho. Early maturing male (jack) and normal-sized (adult) coho (see Table 1) originating from these releases were recovered in the escapement and in the fishery.

The total return of adults from the accelerated release (3.3%) was much lower than the total return from the normal smolts (47.5%). Males predominated among adults from the accelerated smolts; the reverse was true among adults from the normally reared smolts. Adults from the accelerated smolt release were smaller than those from the normal smolts. Hence the overall return of adults from normal smolts was 14 times that from accelerated smolts.

Results of this one study indicate that rearing of accelerated smolts is not economically feasible.

Key words: Spring release, accelerated and normal coho salmon.

RÉSUMÉ

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Dans des conditions normales de piscifacture, des jeunes saumons coho (Oncorhynchus kisutch) sont élevés pendant 14 mois au moins, et, devenus des tacons, sont libérés pour rejoindre la mer. Une réduction de la période d'élevage permettrait de dimineur notablement les coûts. Une façon de réduire cette période serait d'accélérer la croissance du poisson, ce qui produirait en une période plus courte des tacons plus jeunes. Une telle technique présenterait aussi l'avantage de rapprocher la période de reproduction, puisque les saumons adultes atteindraient leur maturité sexuelle au cours de leur deuxième année au lieu de la troisième.

À l'été 1973, on a lancé à Rosewall Creek, dans l'île Vancouver, une expérience de croissance accélérée du saumon coho. Pendant l'hiver 1973-1974, 10,000 jeunes environ ont connu une croissance accélérée et ont atteint le stade de tacon en six mois grâce à des modifications contrôlées de la température, de la photopériode et du taux d'alimentation. Ces jeunes saumons ont été marqués, pourvus d'une étiquette au museau et libérés le 10 juin 1974, en même temps qu'environ 12,000 saumons coho élevés normalement (14 mois) et marqués au museau. Des jeunes mâles matures et des adultes de taille normale (voir tableau 1) qui avaient été libérés à ce moment-là ont été récupérés parmi les saumons de remonte et au cours de la pêche.

Le total des adultes récupérés a été beaucoup bas (3.3%) pour les saumons à croissance accélérée que pour les tacons normaux (47.5%). Les mâles prédominaient parmi les adultes à croissance accélérée, alors que les femelles prédominaient dans l'autre groupe. Les adultes à croissance accélérée étaient plus petits que les adultes normaux. Le produit global des adultes à croissance normale était 14 fois plus grand que celui des tacons a croissance accélérée.

Les résultats de cette étude suffisent à montrer que l'accélération artificielle de la croissance des tacons ne se justifie pas économiquement.

Mots clés: Libération du printemps, saumon coho a croissance accélérée et à croissance normale.

INTRODUCTION

Under normal British Columbia salmon hatchery operations, juvenile coho salmon are reared for at least 14 mo before being released to the sea as smolts. Reduction of the hatchery rearing period could reduce production costs substantially. Length of the rearing period could be reduced by accelerating growth of the fish in water at elevated temperatures (Donaldson 1972). This would result in the production of smolt-sized juveniles in a shorter period of time, and at an earlier age. Such a technique could also have the advantage of increased generation time (Donaldson 1972), whereby adults would mature in their 2nd rather than in their 3rd year of life.

In the fall of 1973, an experiment to accelerate growth of coho was initiated at Rosewall Creek on Vancouver Island. During the winter of 1973-74, approximately 10,000 juvenile coho of mixed Robertson River and Big Qualicum River origin were accelerated to the smolt stage in 6 mo through control of temperature, photoperiod and feeding rate. These fish were marked, nose-tagged, and released on June 10, 1974, along with approximately 12,000 normally reared (14 mo), nose-tagged coho of the same origin. This report compares the contribution of the two groups of smolts to the escapement and to the fishery. It also provides information on the value of growth acceleration as a possible means of reducing production costs by shortening the rearing period prior to release of accelerated smolts.

MATERIALS AND METHODS

Detailed information on rearing, tagging, and release of the normal and accelerated groups of coho is given elsewhere (Bilton et al. 1979). A brief review of these techniques is presented here.

DONOR STOCK AND REARING

ACCELERATED COHO

Coho eggs from the Robertson River (approximately 128 km south of Rosewall Creek) and the Big Qualicum River (approximately 24 km south of Rosewall Creek) were collected in November and December, 1973. The eggs were fertilized and transferred to Heath-type hatchery trays at Rosewall Creek hatchery. Well water was used for incubation. The water was heated using electric immersion heaters, and the eggs were incubated at 10-12°C.

All eggs had hatched by January 7, 1974, at an accumulated total of 473.4 Celcius degree-days.

On February 7, 1974, the resulting fry were transferred to three circular culture tanks (2.44 m diameter x 0.91 m deep) for rearing in heated well water. Over the first 4 days (February 7 to 11) the water temperature was gradually raised from 9° to 16°C. From February 12 to May 30, fry were reared at mean water temperatures ranging from 14.8 to 16.0°C. From May 31 to June 3, the water temperature was gradually decreased to the ambient well water temperature of 7°C. Fish were reared under fluorescent lights and the photoperiod was increased throughout the period of rearing simulating normal day length. Initially fry were fed with Oregon Moist Pellet (OMP) starter mash, and subsequently OMP pellets. Fish were offered food ad libitum every 15 min during daylight hours.

NORMAL COHO

Coho eggs from the Robertson and Big Qualicum rivers were collected in November and December, 1972. The Robertson River eggs were transferred immediately to the Rosewall Creek hatchery. The Big Qualicum eggs were held at the Big Qualicum hatchery until they were "eyed." On January 12, 1973, they were transferred to the Rosewall Creek hatchery. Well water was used for incubation. Eggs were incubated at temperatures ranging between 7 and 8°C.

Between April 3 and 5, 1973, resulting fry were transferred into three identical culture tanks. On July 12, the fish were transferred into one Burrows pond. Fry were reared at ambient temperatures ranging between 3.1 and 16.1°C. The same feeding procedure was followed as for the accelerated coho.

MARKING, GRADING, TAGGING, AND RELEASE OF ACCELERATED AND NORMAL COHO

Between June 5 and 7, 1974, accelerated coho were marked by removal of the adipose fin and tagged using binary-coded wire nose tags. Fish were anesthetized, marked and assigned to one of three size categories (fork length): <82, 82-92, and >92 mm. The first and last categories each represented 25% and the middle category 50% of the fish in the population. Fish were then tagged and transferred to the release pond.

From April 17 to 22, 1974, normal coho were marked and tagged using the same procedure outlined for the accelerated fish. Fish were classified to one of three fork length categories: <102, 102-121, and >121 mm. Tagged fish were transferred to the release pond.

On June 10, 1974, 9,861 tagged accelerated and 11,778 tagged normal coho were released into Rosewall Creek.

METHOD OF RECOVERY AND ESTIMATING CATCH AND ESCAPEMENT

Jack coho salmon were recovered from Rosewall Creek in the fall of 1974, and adults in the fall of 1975. Marked fish (those with a missing adipose fin) were captured in a trap adjacent to the release pond downstream from an electric weir. Unmarked fish (assumed to be wild fish) were transferred alive upstream above the weir.

All marked jacks and adults were killed and sampled for fork length (cm), weight (g), sex and scales. The heads were removed, frozen, and retained for subsequent examination of the nose tag. Nose tags were removed at the laboratory, and the binary coding on each tag was read with a binocular microscope. The number of marked fish without a tag, i.e., those that had lost their tag, was determined. Among those with a tag the number of fish recovered from each of the groups was also determined. For each group of tagged smolts released, the percentage that returned to the escapement as tagged jacks and adults was calculated. The average length and weight of jacks and adults was also calculated for each group.

Nose-tagged coho were recovered in the commercial fisheries (net and troll) by random sampling of fishery catches with a target intensity of 20% (Heizer, Cook, and Argue 1978).

Tagged coho from sport catches were recovered in the Georgia Strait Head Recovery Program (Argue, Coursley, and Harris 1977). This program requested that Georgia Strait and Juan de Fuca Strait tidal sport fishermen voluntarily return heads from chinook and coho salmon having a missing adipose fin. An average "awareness factor" of 0.28 was used to estimate the total number of tagged Rosewall Creek coho that contributed to the sport fishery. This factor is based on a number of values that were not directly measured (Argue, Coursley and Harris 1977). "Rather for Statistical Area groupings in Georgia Strait these factors were assigned on the basis of an area by area comparison with Puget Sound sport fisheries, and use of Puget Sound awareness factors for 1974, documented by Kimura (1976). Assumed Georgia Strait values are therefore referred to as Puget Sound equivalent awareness factors." For each group of tagged smolts released, the percent that was estimated to have been caught by the fishery as tagged immature fish was calculated.

RESULTS

ESCAPEMENT

The return of jacks and adults to the escapement from each release is given in Table 1.

1. Jacks

The total return of jacks from both groups of smolts released was low (0.2% in total). However, the return of 0.4% from the normal smolt release was 13 times greater than that from the accelerated juveniles. Jacks from the normally reared smolt group were of a larger average size than those from the accelerated smolt group. Within the normally reared population, jacks from the "large" smolt subgroup were larger in size than those from the "medium" subgroup.

2. Adults

A total of 52 adults originating from accelerated smolts and 1,191 adults originating from normal smolts returned to Rosewall Creek in the fall of 1975. None were recovered in the fall of 1976. The adult return was 0.53% from the accelerated smolts and 10.11% from the normal smolts. Hence, the return from normal smolts was 19 times greater than that from the accelerated fish.

Among the returning adults from the accelerated smolts, there was a significant deviation ($P < .05$) from the expected sex ratio of 1:1 with 34 males returning of 52 adults (64%) (Simpson, Roe, and Lewontin 1960). For the returning adults from the normal smolts, females were more numerous ($P < .05$), 669 females returning of 1,191 adults (56%).

For the accelerated adults, the highest return of both males and females originated from smolts of the "large" subgroup (average smolt, 14 g). Only one adult returned from smolts of the "small" subgroup (average smolt, 6 g). Among the normal adults, the highest return of both males and females originated from smolts of the "medium" subgroup (average smolt, 17 g), and the lowest from smolts of the "small" subgroup (average smolt, 11 g).

The average weight per adult (Table 1) from the two groups that returned in the escapement differed considerably, with normal fish averaging 3,004 g, and accelerated 2,419 g -- a difference of 585 g (1.29 lb). Within each of the two release groups there were average weight differences between adults from the three subgroups. Among the normal fish, the "small" smolts yielded the smallest aaults and the "large" smolts the largest adults; the mean difference was 517 g (1.1 lb). For the accelerated fish, only the mean weights of adults from the "medium" and "large" smolts could be compared. Here, mean difference was not great (129 g or 0.28 lb).

CATCH PLUS ESCAPEMENT

The total return of adults (catch plus escapement) was 3.3% from accelerated smolts and 47.5% from the normal smolts -- a 14-fold difference in returns from the two groups. The adult return from each of the three size subgroups of normal smolts varied, ranging from 42.1% for the "small"

to 48.3% for the "medium" fish. Among the three groups of accelerated smolts the adult returns differed widely, varying from 0.7% for the "small" to 7.4% for the "large" smolts (Table 1).

For both normal and accelerated fish the catch-to-escapement ratio[1] was highest for the "small" subgroup, indicating selection of smaller fish by the fishery. The overall catch-to-escapement ratio was 78.7% for the normal fish and 84.2% for the accelerated fish (Table 1).

Distributions of both groups in fishery catches indicate that most were caught in the Georgia Strait area (Table 2). Approximately 75% of all normal fish and 64% of accelerated fish caught were taken in this area by the net, troll and sport fisheries. At least half of all fish caught were taken by anglers. Within the normal release group there was a higher rate of exploitation by the sport fishery on those fish of smaller size. However, the heaviest exploitation by the sport fishery on accelerated fish was on those of the large size category. No fish were caught in either the Alaskan or northern B.C. areas. Small percentages were caught in the central west coast of Vancouver Island and Fraser River areas. In general small percentages of both release groups were caught in the Washington-Oregon areas. However, a significant proportion (17.6%) of the medium size category of accelerated fish were caught in the Puget Sound net fishery.

CONCLUSIONS

The adult return from the accelerated coho juveniles was much lower than that from the normal smolts. The overall return of adults from normal smolts was 14 times that from accelerated juveniles. Comparison of the two techniques suggests that accelerated rearing is not economically feasible compared with rearing for the normal period of time. For example, benefit-cost ratios for the two techniques were calculated for the "small," "medium" and "large" subgroups in each release group (Table 3). For the normal fish, benefit-cost ratios varied between 7:1 for the "large" (23 g) fish to 11:1 for the "small" (11 g) fish, suggesting it was more profitable to release smaller fish. For the accelerated fish, benefit-cost ratios ranged from 0.1:1 for the "small" (6 g) fish to 1:1 for the "large" (14 g) fish.

Why did the accelerated smolts not survive as well as the normally reared juveniles? Several reasons may be suggested. First, low survival may have resulted partly from the lack of an objective method for estimating smolting and migration readiness. Recently, a technique to determine the

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[1] $\text{Catch ratio} = \frac{\text{Catch}}{\text{Catch and escapement}} \times 100$

progress of smoltification based on a seawater challenge test has been developed (Clarke and Blackburn 1977). Since this first release, two other releases of accelerated smolts have been made, both incorporating this technique. Returns from these later releases will be evaluated in the light of the improved technology used. Secondly, results of a recent experiment indicate that survival of released fish is influenced to a large extent by both size at and time of release (Bilton 1976, 1978). This size and time study indicates that optimum survival for an early June release would be achieved if fish were of an average size of approximately 18-25 g. Size at release would partly explain the higher survival of both the 14-g "large" accelerated smolts and of the normal 19-g smolts released in early June, as well as the low return from the "small" 6-g and "medium" 8-g smolts from the accelerated group.

How do these returns compare with those from other studies? Senn (1964) presented a report on the results of releasing migrant 0-age coho. Studies were conducted on two groups of hatchery-reared coho induced to migrate to sea at normal migrating size (between 20-80 fish per pound or 22.6-5.7 g average weight) after spending 6 mo in fresh water. Eggs were obtained from coho salmon returning to Chambers Creek near Tacoma, Washington. The progeny of the 1957 and 1961 broods were incubated and reared at 56°F (13.3°C). By the middle of May, following 6 mo of rearing, fish weighing between 29-47 per pound (9.6-15.6 g) were fin-clipped and released. All fish returning from the 1957 brood returned in 1959 as age 0.1 adults. No jacks (age 0.0) returned and only one age 0.2 adult was observed. The returns from the 1961 brood followed an identical pattern. The returns as adults from the 1957 and 1961 broods were 0.5 and 0.4%, respectively. The age 0.1 adults originating from the accelerated hatchery smolts were 1.3 in smaller in size than the parent stocks. The findings were similar to those from this study. Senn concluded the rate of return of the accelerated groups had survival rates within the range experienced by normal hatchery-reared fish. Our experience would indicate that such returns are low when compared with those where the standard hatchery practice of rearing fish for 14 mo is employed.

Donaldson (1972) accelerated coho fingerlings to produce smolts in 6 mo rather than the usual 14 mo. His study was initiated with 1967 brood coho. Six-month-old smolts were released in late May, 1968. Jacks returned in the fall of 1968, and adults returned in 1969 and 1970 as 2- and 3-year-old fish. Two further releases were made. The first was in 1970, the young being the progeny of 2-year-old adults originating from accelerated smolts released in 1967. The second was in 1971, the young being the progeny of 2-year-old adults originating from accelerated smolts released in 1968. Accelerated smolts released in 1970 averaged 6.06 g in weight. The return from this release was 0.03% as jacks, 0.36% as 2-year-old, and 0.13% as 3-year-old adults. The total return was 0.52%. The accelerated smolts released in 1971 included two size groups, those averaging 6.77 g and those averaging 11.81 g in weight. The return of 2-year-old adults (which was incomplete at time of compiling the report) was 1.24% from the smaller smolts and 1.70% from the larger smolts. The overall return was 1.46%. The return from the second release was more encouraging; even so, both returns fell short of those obtained for our normally reared smolts.

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Table 1. Number of normal and accelerated tagged smolts released on June 10, 1974, and the number of jacks[a] and adults[a] from each group represented in the catch and escapement in 1974 and 1975.

			Smolts			Jacks			Adults							
									Escapement			Catch[b]		Catch plus escapement		
Treatment	Stock	Brood year	Size category	Number	Mean weight (g)	(n)	(%)	Mean weight (g)	(n)	(%)	Mean weight (g)	(n)	(%)	(n)	(%)	Catch ratio (%)
Normal	Robertson R. plus Big Qualicum R.	1972	Small	335	11	0	0.0	-	20	6.0	2,626	121	36.1	141	42.1	85.8
			Medium	8,186	17	13	0.2	401	891	10.9	2,969	3,062	37.4	3,953	48.3	77.5
			Large	3,257	23	29	0.9	438	280	8.6	3,143	1,223	37.9	1,503	46.5	81.4
			Total	11,778	19	42	0.4	426	1,191	10.1	3,004	4,406	37.4	5,597	47.5	78.7
Accelerated	Robertson R. plus Big Qualicum R.	1973	small	3,656	6	0	0.0	-	1	0.03	1,180	25	0.7	26	0.7	96.1
			Medium	3,174	8	0	0.0	-	7	0.2	2,332	74	2.3	81	2.5	91.3
			Large	3,031	14	3	0.1	331	44	1.5	2,461	178	5.9	222	7.4	80.2
			Total	9,861	9	3	0.03	-	52	0.5	2,419	277	2.8	329	3.3	84.2

[a]The European system of age designation (Koo 1962) is used. The first digit indicates the number of freshwater annuli and the second the number of ocean annuli. Jacks from normal and accelerated smolts are designated as age 1.0 and 0.0, respectively. Adults from the normal and accelerated smolts are designated as age 1.1 and 0.1, respectively.

[b]Estimates of number of fish in catch are conservative. At release, 93% of smolts were estimated to have a tag. Numbers of smolts released represent only tagged smolts. Recoveries are based only on tagged fish. Hence, there were probably another 7% untagged fish in catch that also originated from these releases.

Table 2. Distribution of normal and accelerated coho in commercial and sport fishery catches in 1974 and 1975.

Treatment	Stock	Size category	Catch	Fisheries[a]															Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Normal	Robertson R. plus Big Qualicum R.	Small	No.	0	3	3	0	9	0	4	3	15	0	84	0	0	0	0	121
			%	0	2.5	2.5	0	7.4	0	3.3	2.5	12.4	0	69.4					100.0
		Medium	No.	2	17	170	9	280	9	80	92	398	6	1676	0	39	91	170	3,062
			%	0.1	0.6	5.5	0.3	9.1	0.3	2.6	3.0	13.0	0.2	54.8	0	1.3	3.0	5.5	100.0
		Large	No.	0	4	95	0	111	0	64	43	176	3	548	43	11	45	53	1,223
			%	0	0.3	7.8	0	9.1	0	5.2	3.5	14.4	0.2	44.8	3.5	0.9	3.7	4.4	100.0
		Total	No.	2	24	268	9	400	9	148	138	589	9	2308	43	50	136	223	4,406
			%	0.04	0.5	6.1	0.2	9.1	0.2	3.4	3.1	13.4	0.2	52.4	1.0	1.1	3.1	5.1	100.0
Accelerated	Robertson R. plus Big Qualicum R.	Small	No.	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	25
			%											100.0					100.0
		Medium	No.	0	0	0	0	8	0	4	5	10	0	33	0	0	1	13	74
			%					10.8		5.4	6.7	13.5		44.6			1.4	17.6	100.0
		Large	No.	0	0	27	8	13	0	4	18	4	0	83	0	0	12	9	178
			%	0	0	15.2	4.5	7.3	0	2.2	10.1	2.2	0	46.6	0	0	6.8	5.1	100.0
		Total	No.	0	0	27	8	21	0	8	23	14	0	141	0	0	13	22	277
			%	0	0	9.7	2.9	7.6	0	2.9	8.3	5.1	0	50.9	0	0	4.7	7.9	100.0

[a]Fishing areas and gear

1 Central B.C. troll (areas 1-5)
2 Northwest Vancouver Island troll (areas 25-27)
3 Southwest Vancouver Island troll (areas 21-24)
4 Washington Oregon troll
5 Georgia Strait troll
6 Northwest Vancouver Island net (areas 25-27)
7 Juan de Fuca net (area 20)
8 Johnstone Strait net (areas 25-27)
9 Georgia Strait net
10 Fraser River net
11 Georgia Strait sports fishery
12 Oregon troll
13 Washington sport
14 Washington troll
15 Puget Sound net

Table 3. The estimated benefit-cost ratios from releases of 100,000 normal and accelerated coho smolts of different sizes in each case for all fish minus jacks.

Treatment	Smolt size (g)	Jacks		Adults										
				Escapement		Catch		Catch plus escapement						
		No.	Biomass (lb)	No.	Biomass (lb)	No.	Biomass (lb)	No.	Biomass (lb)	Cost/lb smolts ($)	Wt.(lb) 100,000 smolts	Cost 100,000 smolts ($)	Total value catch plus escapement ($)	Benefit/cost ratio ($)
Normal	11 (S)	0	0	6,000	34,781	36,100	209,267	42,100	244,048	8.34[a]	2,428	20,249	231,846[b]	11:1
	17 (M)	200	177	10,900	71,439	37,401	245,122	48,300	316,561	8.34	3,752	31,292	300,733	10:1
	23 (L)	900	870	8,600	59,668	37,900	262,957	46,500	322,625	8.34	5,077	42,342	306,494	7:1
	19 (T)	400	376	10,100	66,977	37,400	248,012	47,500	314,989	8.34	4,194	34,978	299,239	8:1
Accelerated	6 (S)	0	0	30	78	700	1,823	730	1,901	11.07[c]	1,324	14,657	1,806[d]	0.1:1
	8 (M)	0	0	200	1,029	2,300	11,841	2,500	12,870	11.07	1,766	19,549	12,226	0.6:1
	14 (L)	100	73	1,500	8,149	5,900	32,053	7,400	40,202	11.07	3,090	34,206	38,192	1:1
	9 (T)	30	22	2,670	2,670	2,800	14,952	3,300	17,622	11.07	1,987	21,996	16,741	0.8:1

[a]Based on cost 35¢/smolt for production of 19-g smolts in this experiment.

[b]Based on sale price 95¢/lb., assuming all fish were recovered and sold at the hatchery.

[c]Based on cost 22¢/smolt for production of 9-g smolts in this experiment.

[d]Based on sale price 95¢/lb., assuming all fish were recovered and sold at the hatchery.